Ontological Approach to Military Knowledge Modeling and Management

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ABSTRACT

Ontologies have received increasing interest in the computer science community and their benefits are now recognized for military applications. In addition to explicitly encode a shared understanding of some domain, ontologies can be used in a wide range of applications including natural language processing, intelligent search engines, information retrieval, or as a means to facilitate interoperability between heterogeneous knowledge sources at a high level of abstraction. Our objective is to contribute to the building of ontological models in the information fusion domain and to exploit these models to provide enhanced knowledge management assistance to military commanders. In the paper, we first review the roles of ontologies for military applications. Then, we describe the characteristics of high-level information fusion processes and address methodological aspects related to ontological engineering. This leads us to derive an ontological approach to situation and threat assessment domain modeling. Finally, we present ontology-based knowledge management services that could be exploited in support of high-level information fusion processes.

1.0 INTRODUCTION

In military environments, commanders and their staff are overwhelmed by the increasing amount of information available to them. Large volumes of information and data from heterogeneous information sources have to be integrated and interpreted in order to gain situational awareness. Both structured and unstructured data sources have to be managed. In the first case, different data models and formats have to be considered. In the latter, content extraction from unstructured data (e.g. military messages containing free text) using natural language processing techniques are required. Furthermore, the techniques being developed for data fusion and resource management in Decision Support Systems for Command and Control are becoming increasingly more sophisticated, particularly through the incorporation of methods for high-level reasoning processes.

Providing commanders with intelligent information fusion systems or advanced decision aids requires a good understanding of the processes involved, their information requirements, and the development of formal domain models upon which reasoning processes can be based (e.g. knowledge-based systems, intelligent agents). In this context, we aim at contributing to the building of ontological models that could be used to automatically support information fusion processes. Furthermore, these models would enhance knowledge

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management services for information fusion and would provide commanders with a gain in situational awareness.

Ontologies have received increasing interest in the computer science community and their benefits are now recognized for military applications as they provide a foundation for the representation of domain knowledge. They explicitly encode a shared understanding of a domain that can be communicated between people and application programs. Gruber [6] defines an ontology as « *an explicit specification of a shared conceptualization* ». The specification of an ontology comprises a vocabulary of terms, each with a definition specifying its meaning. Ontologies range from controlled vocabularies to highly expressive domain models [12]: integrated data dictionaries designed for human understanding, taxonomies organizing concepts of a domain into inheritance hierarchies, structured data models suitable for data management, and finally highly expressive computational ontologies. In addition to explicitly encode a shared understanding of some domain, ontologies can be exploited in a wide range of applications including natural language processing, intelligent search engines, information retrieval, or as a means to facilitate interoperability between heterogeneous knowledge sources at a high level of abstraction.

Ontologies can play different roles for knowledge modeling and management in military applications. First, ontological models constitute a language that facilitates communication between a community of agents: communication between humans, interaction between humans and computers, and communication between computer applications, software agents or multiagent systems. From a knowledge modeling perspective, ontologies provide domain models representing a shared understanding of some domain that can be reused across a wide range of applications in that domain. The development of larger and more complex intelligent systems in knowledge-intensive domains make impractical to develop knowledge bases from scratch. Thus, knowledge engineering promotes the design of libraries of reusable components that include both ontologies and problem-solving methods. Consequently, the design of ontologies is considered as a pre-requisite to the development of large knowledge bases (e.g. HPKB DARPA program). These models provide a support for the development of data fusion systems or decision support systems for command and control by system engineers and knowledge engineers. Predefined ontologies can then be exploited to provide more advanced knowledge management services.

Most significant modeling efforts in the military domain have been devoted to planning activities. Common representation of plans has been a subject of interest for a long time. Among the work reported in the literature, some aim at providing plan models (e.g. O-PLAN, SPAR, PLANET), whereas other focus on the representation of courses of action (COA), i.e. outlines of plans, for example, the Disciple-COA project from the DARPA HPKB and RKF programs. Bowman's work [4] extends the COA ontology to represent the military concept of Center of Gravity used at the strategic level. In the context of military data models, the NATO LC2IEDM (Land C2 Information Exchange Data Model) is also of great value because it stores the core data needed to describe information to be exchanged between C2 systems with respect to the battlefield domain. Few researches have been devoted to analyze high-level data fusion processes from an ontological perspective. W. Johnson and his colleague [7] present an ontological analysis for situation and threat assessment and describe the different types of relations between objects of the domain. M. Kokar describes a formalization of situation awareness of in [2]. As ontologies aim at building reusable components, these models should be analyzed in order to contribute to the representation of high-level information fusion domain knowledge.

Our objective is to contribute to the building of ontological models in the information fusion domain and to exploit these models to provide enhanced knowledge management assistance to military commanders. The remainder of the paper is organized as follows. First, we describe the characteristics of high-level

information fusion processes. Then, we address methodological aspects related to ontological engineering. This leads us to derive an ontological approach to situation and threat assessment domain modeling. Finally, we present ontology-based knowledge management services that could be exploited in support of high-level information fusion processes.

2.0 CHARACTERISTICS OF HIGH-LEVEL FUSION PROCESSES

Data fusion is the process of combining data from multiple sources to refine state estimates and predictions [14]. In a perspective to provide a unifying terminology and a shared understanding of the domain within the Data Fusion community, efforts conducted by the Joint Directors of Laboratories (JDL) Data Fusion Working Group have resulted in the refinement of a process model for data fusion [14]. The JDL model is the most widely accepted model of the data fusion process. It is divided into four levels (the sub-object data assessment being excluded). The definitions are as follows.

Level 1 – Object assessment: Estimation and prediction of entity states on the basis of observation-to-track association, continuous state estimation and discrete state estimation. The product of this level consists of tracks, i.e. hypothesized entities with their type and identity.

Level 2 – Situation assessment: Estimation and prediction of relations among entities, to include force structure and cross force relations, communications and perceptual influences, physical context, etc. This involves associating tracks into aggregations. The state of the aggregate is represented as a network of diverse relations among its elements.

Level 3 – Impact assessment (or Threat assessment): Estimation and prediction of effects on situation of planned or estimated actions by the participants, to include interactions between action plans of multiple players. The product is the impact estimate of the assessed situation, i.e. the outcome of various plans as they interact with one another and with the environment.

Level 4 – Process refinement: Metalevel process consisting of adaptive data acquisition and processing to support mission objectives.

In the same perspective, J. Roy [13] attempts to synthesize the main notions put forward by data fusion and situation awareness models into a situation analysis model. He defines Situation Analysis (SA) as *a process, the examination of a situation, its elements, and their relations, to provide and maintain a product, i.e. a state of Situation Awareness (SAW), for the decision maker*. The proposed SA model captures the representation of various elements of the situation as well as how they relate to create a meaningful synthesis, i.e., a comprehension of the situation. It includes: situation element acquisition, data alignment and association, situation element perception refinement, situation element contextual analysis, situation element interpretation, situation classification and recognition, situation assessment, situation element projection, impact assessment, situation watch, and process refinement. By describing the different functions involved in the SA process, the model provides a basis for the building of domain models and problem-solving methods related to the processes.

New efforts within the information fusion community aim at formalizing the concepts related to high-level information fusion with the objective to improve human understanding across the data fusion community (e.g. defence researchers and system developers), and ultimately facilitate communication between distributed fusion systems. In this context, an ontology for high-level data fusion captures the main concepts and

relationships between concepts at these levels. The ontology should specify both physical and non-physical entities involved in level 2 (situation assessment) and level 3 (threat assessment) information fusion processes.

High-level fusion processes are complex processes involving many elements and interactions among a wide variety of battlefield components. In particular, a large number of data items are included and used in the processes. High-level data fusion processes have the following properties:

- They emphasize on symbolic reasoning rather than numeric reasoning;
- Hierarchical reasoning is required due to vertical organization of military entities and the multiple levels of abstraction nature of the reasoning process. Objects involved in the data fusion process are organized in multiple levels of abstraction where objects at one level are linked to objects at an adjacent level (e.g. entities aggregation).
- Reasoning in context is performed: data are analyzed with respect to the evolving situation including environmental considerations.

Concepts involved in high-level data fusion processes have specific characteristics:

- They manipulate both concrete and abstract entities;
- Multiple types of dynamic and static domain knowledge have to be processed;
- There exist numerous constituency-dependency relationships among objects as well as events and activities of interest;
- Reasoning in context exploits domain feature databases to facilitate hypothesis management. Thus, it requires a data representation that supports efficient spatial and semantic search.

Before presenting some of the relevant concepts to be incorporated in a baseline ontology for information fusion, we provide some guidelines for construction of ontologies.

3.0 ONTOLOGY CONSTRUCTION METHODOLOGY

The development of ontologies is a modeling activity that is complex and time-consuming. Therefore, methodologies have emerged based on experiences gained in the construction of large ontologies. A survey of these methodologies is presented in [8]. These aim at making the development of ontologies more an engineering process rather than an art. The main stages that can be derived from these methodologies consist of the following:

- Definition of the requirements for the ontology (purpose and scope);
- Building informal specification of concepts (taxonomy);
- Formally represent the concepts and axioms in a language (ontology);
- Evaluation of the ontology.

The purpose of an ontology defines its intended use, and the scope of an ontology delimitates the world to be modeled. The next step in the process consists of identifying the most important concepts in the domain, build a lexicon for these terms, and derive a comprehensive taxonomy of terms of the domain. The use of a mixed top-down and bottom-up approach to ontology development is recommended. The top-down mode may extend the definition of concepts from an existing upper-level ontology, i.e. establish links to upper-level

categories that have already been defined within large ontologies (e.g. CYC) or relevant military models (e.g. NATO LC2IEDM data model). The bottom-up approach adds more specific concepts from additional reference sources (e.g. glossaries, terminology or domain databases, etc.).

The semantics of concepts in the ontology is specified through their definition, their properties, relations with other concepts, and eventually axioms that formally specify definitions and constraints of terms in the domain. Usually, an ontology is decomposed into subdomains organized into different hierarchies of concepts. Top-level concepts being at the top of class hierarchies are sometimes called microtheories, (e.g. Military equipment).

An important aspect in the ontology development process is to explicitly establish relationships that exist between concepts. Some of the relations that can be defined between concepts are:

- Relations that link a concept with more specific concepts (*is-a/subsume* relation);
- Relations that link a complex object to its constituents (*part-of/contains* relation);
- Any variety of relations that should be specified. These relations include for example causal, functional dependencies, or temporal relations.

A thorough analysis of the processes to be supported by the ontology should be performed as well as an analysis of the relevant data/knowledge sources involved in the processes. Ontological engineering could be seen as the domain modeling component of a global knowledge engineering method for the design of intelligent systems (knowledge-based systems, knowledge management systems, knowledge portals, etc.). For example, the CommonKads method for knowledge engineering and management incorporates the ontology building process in its knowledge model. IDEF is a method widely used within the military community designed to model the decisions, actions, and activities of an organization or system that incorporates an ontology capture method (IDEF5). In some cases such as knowledge-intensive military environments, a Cognitive Work Analysis (CWA) is performed to analyze the cognitive processes involved, and provide a functional decomposition of the processes and their information requirements. Such analysis should help derive and/or refine the concepts of the ontology, and better determine the scope of the ontology.

Moreover, the development of ontologies should be an incremental process, validated by subject matter experts at each stage of the process, and should maximize subsequent reuse and extensibility.

In the case where the ontology is exploited as a language to facilitate access to heterogeneous sources, a mapping has to be provided between the concepts of the ontology and the meta-models of the different data sources (description of the content of the sources, i.e. data models, or meta-data).

The whole ontological engineering process is presented in figure 1.

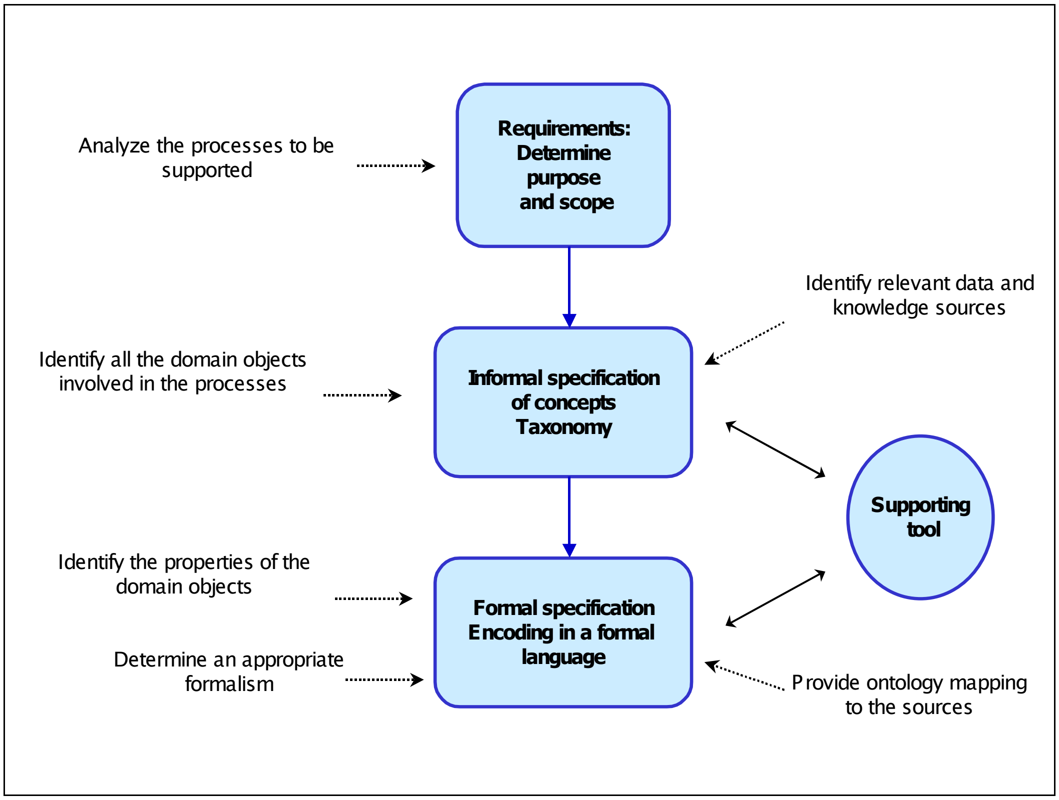

Figure 1: Ontology development process.

An ontology representation language has to be chosen to encode the ontology. The degree of formality of the ontology is mainly determined by the purpose of the ontology. If the ontology is a framework for communication among people, the representation can be informal, but if the ontology is to be used by software tools or intelligent agents to support automated tasks, then a more formal representation is required [16]. Different formalisms and knowledge representation languages have been proposed to describe ontologies. Some are limited to describing concepts, attributes, and relations and resemble conceptual models in databases or object-oriented models (ex. UML class models). UML has recently been extended to become a suitable candidate to support ontological engineering. Other formalisms use knowledge representation paradigms such as first-order logic, frame-based or description logic. New developments within the Internet community and the semantic Web have led to new ontology languages proposals such as DAML+OIL [5,11], or OWL (Ontology Web Language) [10]. An appropriate ontology language for high-level information fusion modeling would allow the formal specification of information fusion concepts, their properties and the different types of relationships that exist between concepts. This specification should serve as a basis for automated reasoning.

Ontological engineering requires environments to facilitate the process of building and maintaining ontologies, especially when the number of concepts and relationships become large. Such tools provide functions to edit concepts, browse the ontology, etc. They should facilitate the integration of existing ontologies, and the translation from the original formalism to some standard (e.g. RDF Schema, DAML+OIL, or OWL).

4.0 ONTOLOGICAL APPROACH FOR HIGH-LEVEL FUSION KNOWLEDGE MODELING

Ontological engineering for high-level fusion can be performed by analyzing Level 2 and 3 fusion processes in order to characterize the most important concepts that are part of these processes, and derive a specification for these concepts. This process constitutes a problem-oriented approach to ontology creation.

4.1 Situation Assessment

While level 1 data fusion deals with concrete entities such as emitters, platforms, low-level military units, level 2 and 3 are more concerned with abstract entities (e.g. event, intent, or goal).

Situation Assessment attempts to answer the questions: who is out there? Where are they and what are they doing? How are they situated? Which kinds of units are formed?

The output of Level 1, i.e., information about individual objects, their position, movement and identity, is aggregated into a composite tactical picture at Level 2. This concerns the situation assessment issue that leads to a more symbolic representation of the environment and the relationships among the entities and the events in it, to produce a higher-level of statement of what is really happening. Situation assessment focuses on relational information to determine the meaning of a collection of entities (into combat units and weapon systems), by aggregating the objects by location and type. The location attribute helps determine if an entity is part of an aggregation. Knowledge of the types of units helps determine what kind of actions, operations and strategies are possible. Hostile behaviour patterns help to establish whether the situation corresponds to a normal activity, threatening conditions, a suspicious activity, etc.

Environmental information (terrain, surrounding media, hydrology, weather, sea-state, underwater conditions) is taken into account in the situation assessment process. Thus, models of terrain, oceanography and meteorology have to be provided.

Figure 2 illustrates some important elements of Level 2 fusion that should be further refined and specified in the ontology. Relationships are not specified here, but typical relationships between entities include constituency-dependency, causal, temporal relations or geometrical proximity. In particular, temporal and spatial relationships should be carefully specified. Moreover, functional relationships that group entities carrying out the same functions have to be specified.

Ontologies of time and space are particularly important in military domains because reasoning in a dynamic world requires a formal means to describe spatial and temporal entities. For example, the order and sequence in time in which the entities are observed are crucial for their interpretation. Moreover, the analysis of movements of entities gives some indications on their intention (offensive or defensive).

Different time structures can be considered, such as point structure or interval structure. For the latter, a set of relations on temporal intervals proposed by Allen consist of the following: equals, before, meets, overlaps, starts-by, contains, ended-by. A space ontology concerns the representation of points or regions objects and relations amongst them. In a dynamic world, objects are located in time and space (notion of motion). Thus, representations of time and space have to be combined.

Different ontological models of time and space are described in [15]. Standardization efforts are also reported within the DAML community.

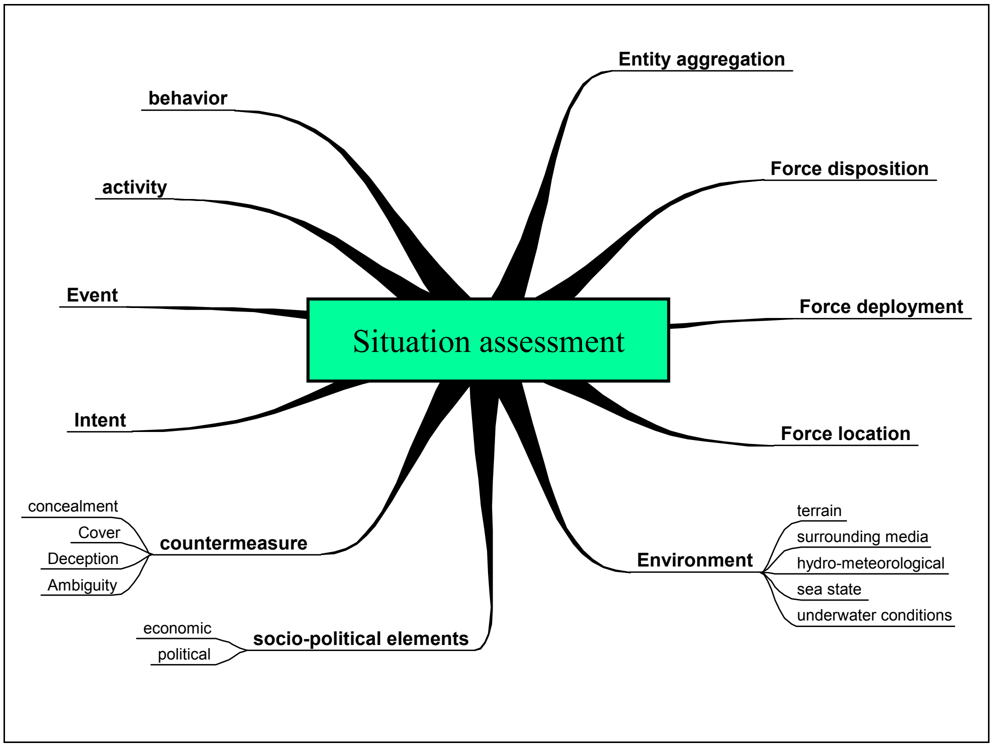

Figure 2: Elements of Situation Assessment.

4.2 Threat Assessment

The highest level of data fusion is the threat assessment level, or impact assessment (i.e. level 3), that projects the current situation into the future and infers about the impact of the assessed situation, the friendly and enemy vulnerability, the force capabilities, and determine levels of danger. Threat assessment attempts to answer questions such as: what is the overall force level? What is their readiness? How effective are they? What are their intentions? What are their goals? What are their strategies? What can we do about it? What will be the outcome of engagements?

Threat assessment aims at determining engagement outcomes as well as assessing an enemy's intent based on knowledge about enemy doctrine, level of training, political environment, etc. The focus is on intent, capability and opportunity [9]. These elements are depicted in Figure 3.

A major element of threat assessment is the prediction and evaluation of the enemy most probable courses of action. Thus, plan or courses of action (outlines of plans) models from the military domain that encapsulate important planning concepts (e.g. goal, action, event) are of interest here.

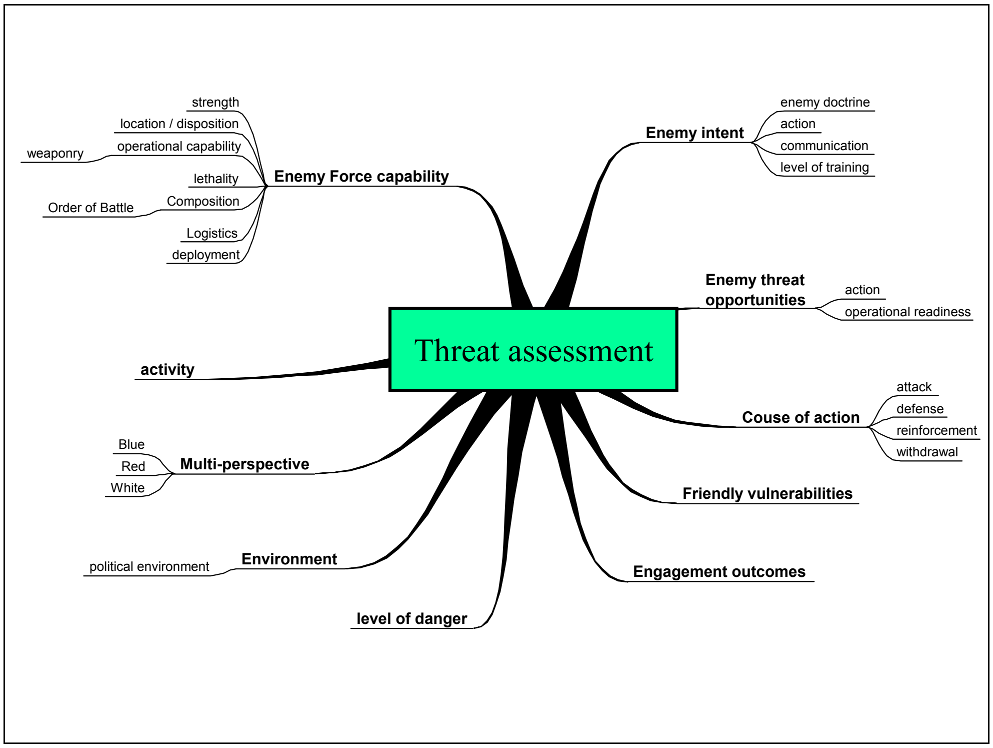

Figure 3: Elements of Threat Assessment.

5.0 ONTOLOGY-BASED KNOWLEDGE MANAGEMENT SERVICES

Complex military environments require knowledge management techniques and tools to deal with information overload, to exploit available data from different sources in multiple formats, to provide effective access to information, to analyze large data sets using intelligent data mining techniques, and to facilitate content extraction from unstructured data using artificial intelligence and natural language processing techniques, etc.

Ontological models can be exploited to provide more advanced knowledge management services. First, ontologies facilitate interoperability between heterogeneous knowledge sources by providing a knowledge-level description of a domain that can be mapped to heterogeneous data or information sources. Secondly, in military environments where an increasing volume of both structured and unstructured information has to be digested (e.g. the intelligence domain), ontologies can be exploited to index semi-structured information sources, to help extract semantic content from unstructured data, and to provide more advanced knowledge management services such as categorization of documents or ontology-based search engines.

5.1 Ontologies for Information Integration

Level 2 and 3 information fusion processes require a significant amount of a priori database information to support the components analyses. Information sources supporting information fusion processes are in different forms and formats. Major categories of databases required for level 2 and 3 data fusion are provided in [17]. Representational techniques to support data fusion processes are usually spatial and object-oriented [1].

However, high-level information fusion processes also exploit military doctrine, procedures, or lessons learned, usually expressed in semi-structured textual format.

The KNOWMES project (KNOWledge Management and Exploitation Server) conducted at DRDC-Valcartier aims at providing an ontology-based knowledge server that exploits a priori databases containing heterogeneous information in support of Situation/Threat Assessment and Resource Management (STA/RM) [3]. The proposed server relies on a three-tiered architecture that includes an ontology layer (cf. figure 4). The client tier provides various knowledge management functions available to the user, such as search and retrieval, knowledge base browsing, and handles user interactions. The middleware layer implements the knowledge management services. It includes an ontology server to manage and exploit ontologies, as well as an ontology mapper that links the ontology to the sources (through their models). The data tier concerns the heterogeneous information sources, namely an object-oriented database, a GIS database, and an XML repository. The object-oriented database contains a priori data to support the different fusion levels (e.g. descriptive information about military equipment, object behaviour patterns, formation, communication scheme, weapon and sensor capabilities). It has been chosen due to its capability to organize objects and relationships between objects [1], and to manage them effectively. The GIS database contains geographical and topological information such as terrain elevation, roads, buildings, or commercial corridors. The XML database contains documents of relevance for high-level fusion processes, such as doctrine, standard operational procedures, or rules of engagement.

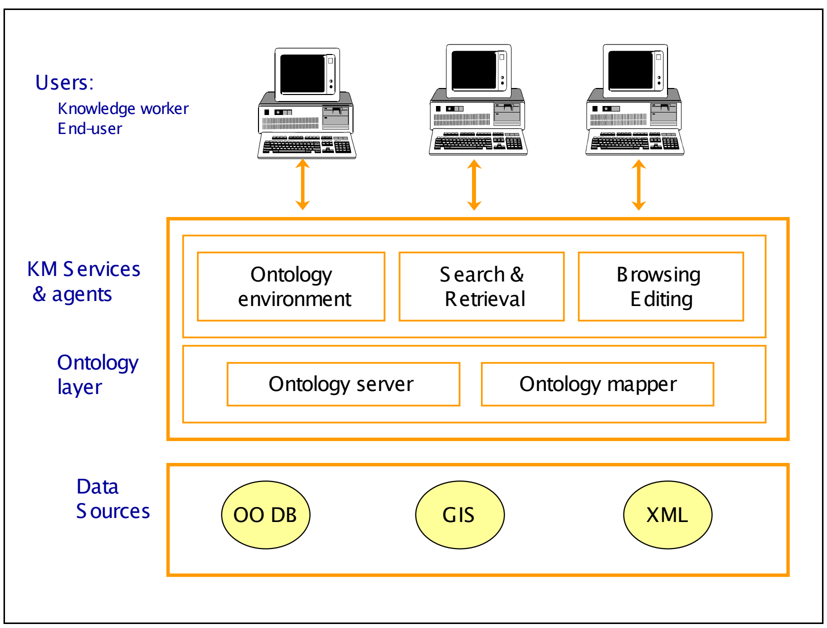

Figure 4: Architecture of KNOWMES.

5.2 Advanced Search Engines

The exploitation of ontologies for query-answering is twofold:

1) query formulation,

2) query interpretation and processing.

First, an ontology can serve as a language to express queries. Using a common terminology, users can formulate queries without worrying about exact names of the entities in the data sources nor the structure of the underlying data sources. An ontology browser may be available to present the ontology structure to the user who can then select the concepts of interest. A common terminology facilitates also a unified access to multiple sources. A federated search mechanism has to reformulate user queries (expressed using the ontology) in the query languages of the different sources (e.g. SQL statement for relational databases).

The ontology itself can be exploited to improve query-answering mechanisms. Ontologies can be exploited to enhance search engines mechanisms by analyzing relationships between concepts and thus providing more relevant results (e.g. remove noisy results or redundancies, enable search refinement). The relationships linking concepts (i.e. abstraction and composition) can be used to extend or refine queries. For example, a search for information about *helicopter* will derive a search for information for *CH-146* given that *CH-146* is a type of *helicopter*. So, documents about *CH-146* will be retrieved even if they do not contain the word *helicopter*. More complex relations and their properties could be exploited to process queries and draw inferences leading to more relevant results. Moreover, ontology-based search engines should also take into account synonyms of terms that are incorporated in the ontology. Then, the search engine looks for the terms specified in the query as well as their synonyms. Acronyms should also be considered when their definition is available in the ontology. These mechanisms are incorporated in a prototype under development to enhance search capabilities within a lessons learned management system for the Canadian Forces.

Finally, retrieving information by exploitating ontological models and by taking into account the context of a current situation should lead to more relevant and accurate results for the decision maker.

5.3 Ontologies for Document Categorization

Military organizations have to deal with an increasing number of documents coming from different sources and in various formats. These documents have to be screened, analyzed and categorized in order to interpret their content and gain situation awareness. They should be categorized according to their content to enable efficient storage and retrieval A better categorization and management of information would facilitate correlation of information from different sources, avoid information redundancy, improve access to relevant information, and thus better support decision-making processes.

Ontologies, or the taxonomy aspect of ontologies, can be exploited as a support for automatic document categorization. On one hand, they organize concepts in a hierarchical structure that can be utilized for categorization (e.g categories of Yahoo). On the other hand, they provide the semantics of a domain that can be exploited to improve traditional classification methods based on statistics. Providing a formal model of a domain through ontologies, or classification of terms through taxonomies has often been identified of potential utility to support information extraction from texts or for automated document indexing. For example, WordNet, a large electronic lexical database publicly available may be used to support information extraction or query formulation. But it is considered not suitable for processing texts in specific domains.

Natural language processing techniques supported by a domain ontology can be used to extract semantic meaning from unstructured text and provide semantic indexes from the ontology. An ontology-based semantic analysis consists of analyzing candidate concepts resulting from the statistical analysis from a semantic perspective by exploiting a domain ontology, in order to restrict the document descriptors to the attributes that semantically characterize the text (e.g. remove poorly meaningful words). At each level of the ontology structure, specific semantic expressions are attached to concepts, to guide the semantic processing. A semantic search engine is used to search for semantic similar expressions in documents being processed.

This allows the system to refine the semantic analysis of the document and thus provides a fine-grained documents categorization.

Some research projects exploiting ontologies have been undertaken at DRDC-Valcartier to organize military knowledge bases and search for information more effectively. In particular, Lessons Learned knowledge warehouses contain relevant experiential knowledge reported from previous missions (observations, issues, recommendations) expressed in natural language with many acronyms and abbreviations. If these knowledge sources are adequately indexed and organized along a taxonomy of the domain, they can be exploited by military officers to effectively retrieve information when assessing a situation or when planning a new mission. Moreover, we are conducted some experiments in order to exploit both statistical methods and semantics relying on an ontology for automatic document classification in the terrorism domain to help military officers facing information overload.

6.0 CONCLUSION

In this paper, we have presented an ontological approach to military knowledge modeling and management, in particular for high-level information fusion. We have also illustrated how these models could provide enhanced knowledge management assistance to military commanders. As ontologies promote knowledge reuse and sharing, we should benefit from previous models built in related domains.

Beside the KNOWMES project related to knowledge management in support of information fusion, several research projects conducted at DRDC-Valcartier aim at exploiting ontological models. This includes the building of a situational awareness knowledge portal, the management of lessons learned, and the design of an automatic document analyzer and classifier. The work presented herein and the other ongoing initiatives should benefit from each other.

Finally, there are some ontological engineering issues that have not been addressed here, for example, the maintenance and exploitation of extensible ontologies, and the integration/mapping of several ontologies within different military environments. These aspects are important and should be analyzed further.

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DEFENCE R&D DÉFENSE

Ontological Approach to Military Knowledge Modeling and Management

Application to Information Fusion

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21 October 2003

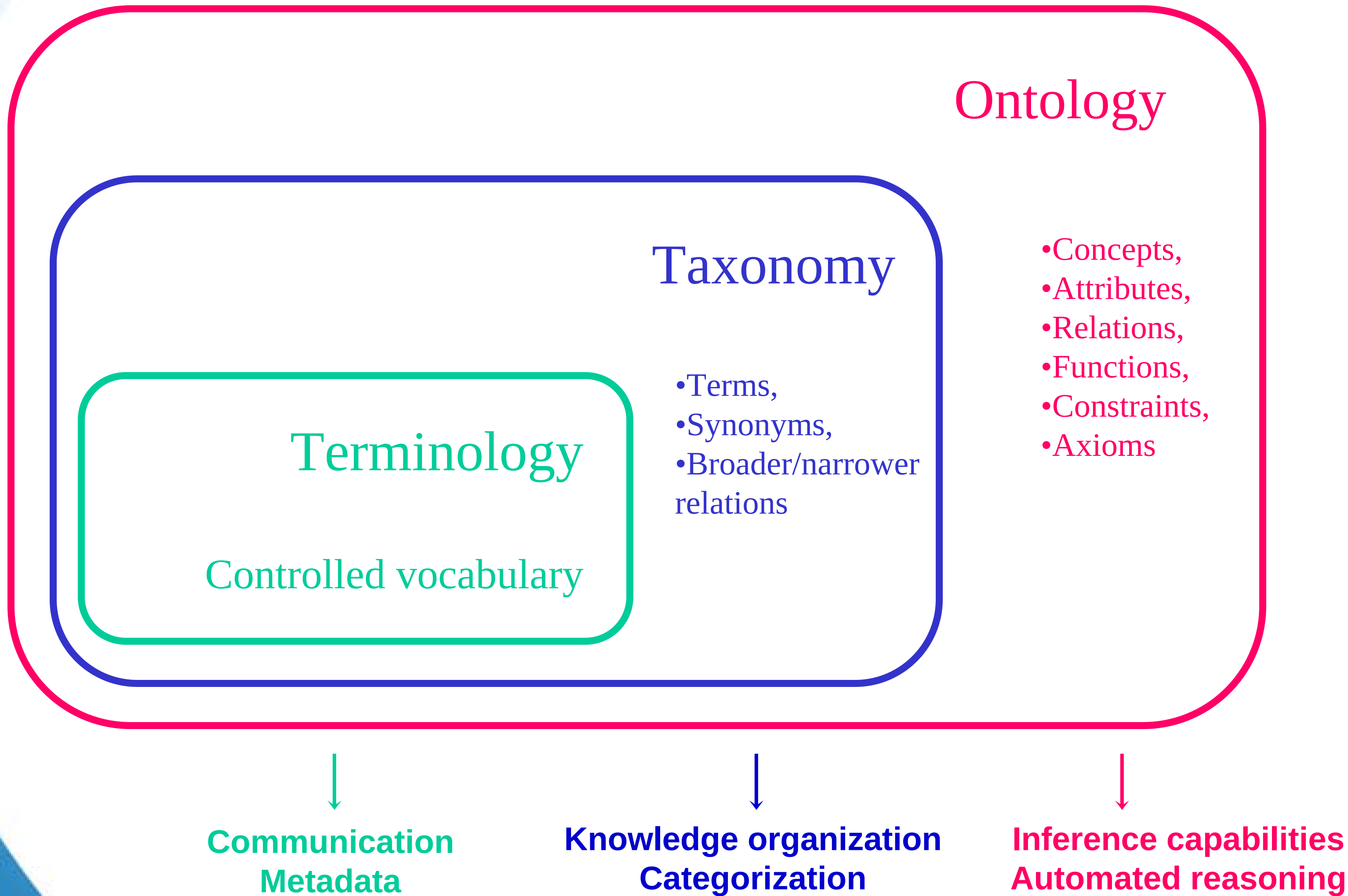
Defence Research and Development Canada
Recherche et développement pour la défense Canada

Canada

Objectives

- Building of ontologies to support information fusion processes
  - Conceptual Modeling for High-level Information Fusion
  - Ontological Engineering
    - Methodology
    - Formalism and Tools
- Exploitation of ontologies: Ontology-based Knowledge Management Services
  - Semantic integration (Knowledge server)
  - Advanced search engine
  - Document Categorization

Terminologies, Taxonomies, Ontologies



Examples of ontological military models

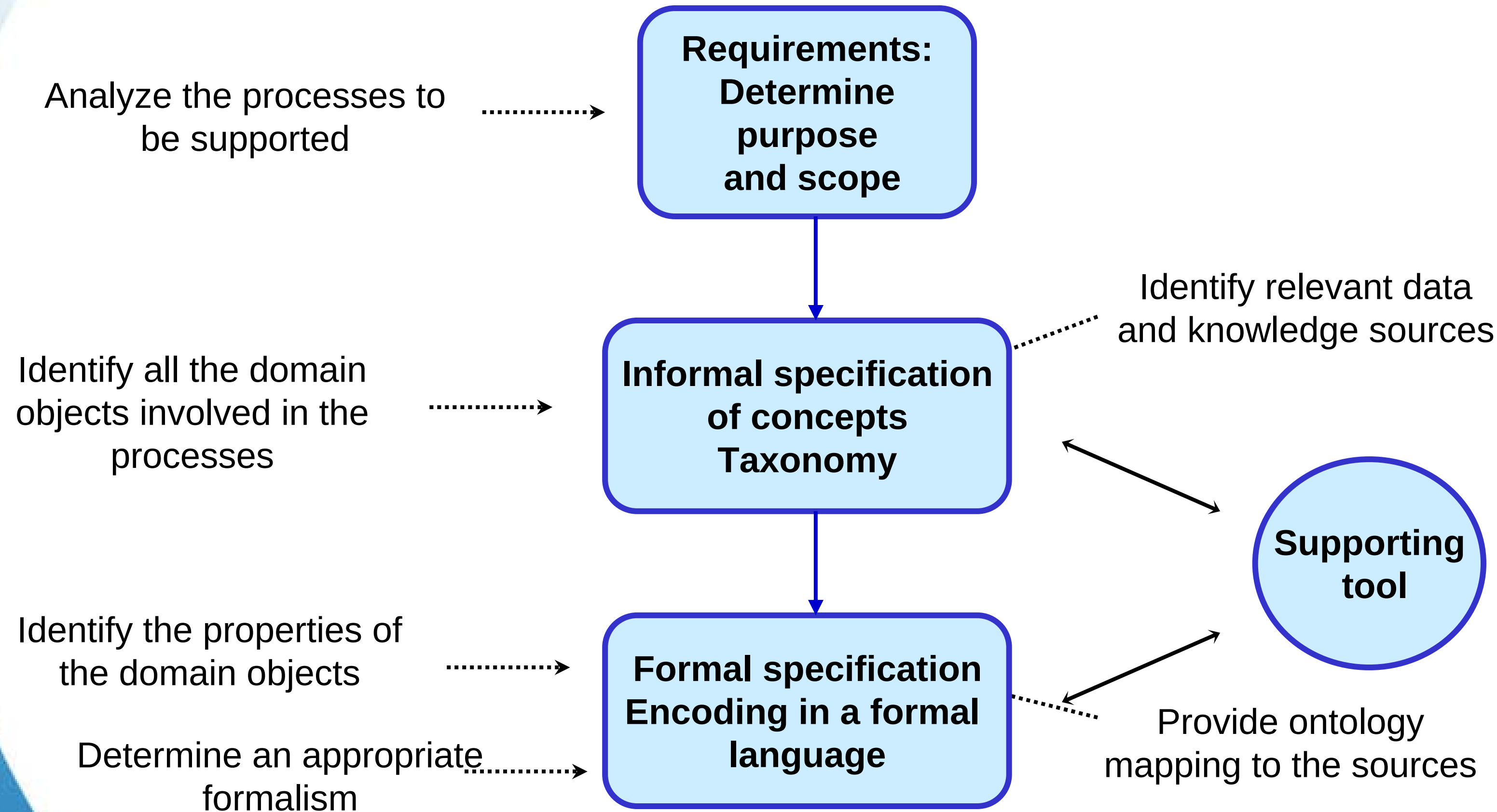
Military models

	NATO	DARPA
Initiatives	NATO C2IEDM / GH Data Model	DARPA ARPI / SPAR HPKB / RKF
Scope	Battlefield (Army, Joint)	Plan representation Battlespace / COA Analysis
Objects	Object Action Capability Location Context Target-list Reporting-data Rule-of-engagement	Plan Activity Objectives Environment Process Evaluation-criteria Time-interval Activity-constraints Center of Gravity

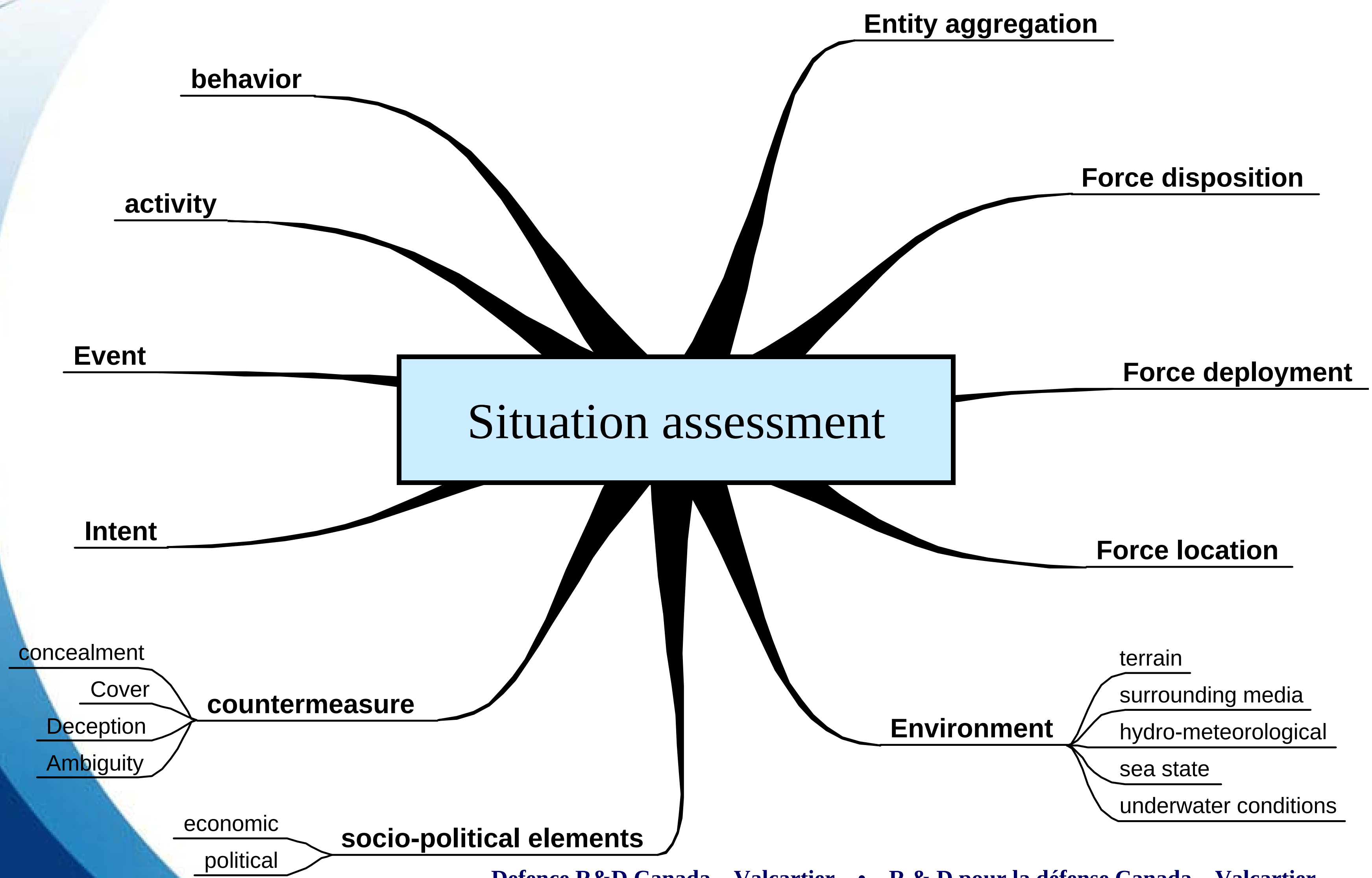
Characteristics of High-Level Information Fusion

- High-level information fusion processes
  - Emphasize on symbolic reasoning
  - Hierarchical reasoning – Multiple levels of abstraction
  - Reasoning in context
- High-level information fusion concepts & relations
  - Both concrete and abstract entities
  - Numerous constituency-dependency relations between concepts
  - Vertical organization of military entities
  - Both static and dynamic domain knowledge

Problem-oriented ontology development



Elements of Situation Assessment



Relationships between concepts

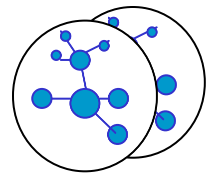
- De facto relationships in ontologies
  - Is-a (abstraction of concepts)
  - Part-of (composition)

- Other important relationships
  - Temporal (starts-by, ended-by, overlaps, etc)
  - Spatial, geometrical proximity
  - Functional dependency
  - Causal

Ontologies for Knowledge Management

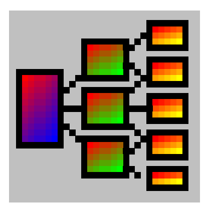
Shared understanding

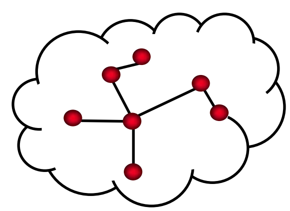
Knowledge sharing

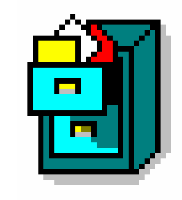


Formal specification

Reusable components







Knowledge structuring

Search engines Filtering

Knowledge categorization

Exploitation of ontologies

Problems

- Exploit available data from heterogeneous sources,
- Deal with information overload,
- Provide effective access to information,
- Facilitate content extraction from unstructured sources

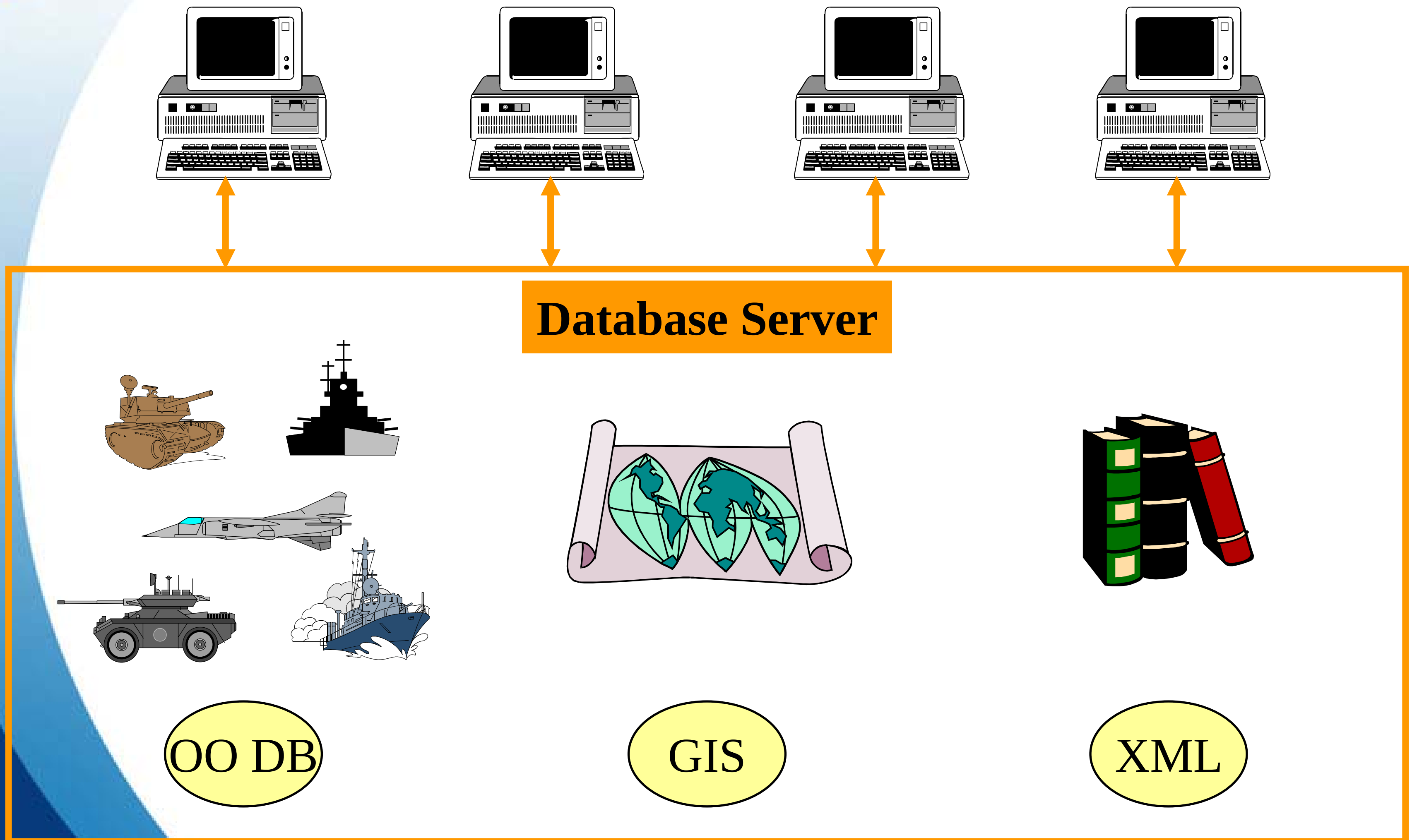
Some solutions

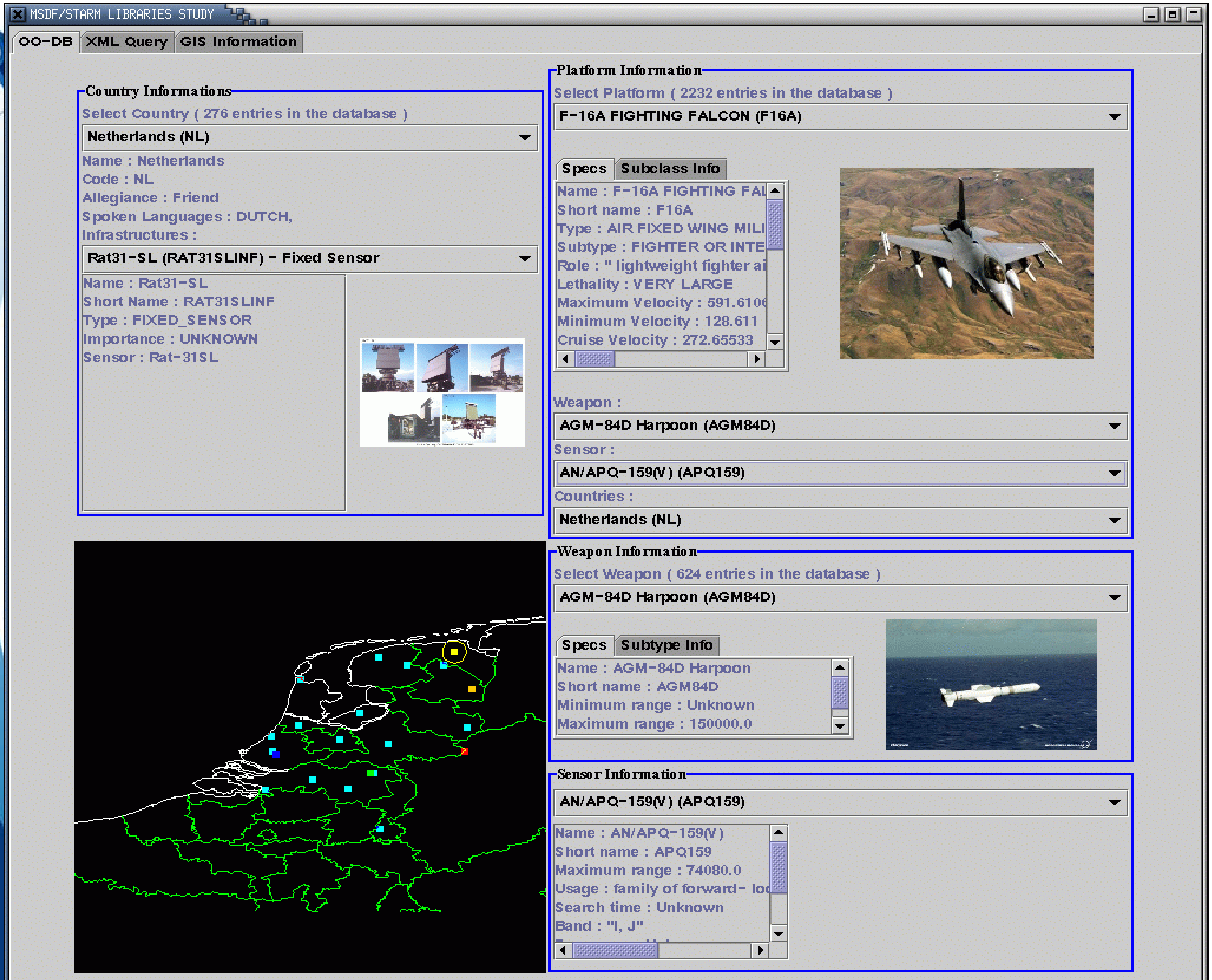
- Semantic integration of heterogeneous sources
- Ontology-based search & retrieval
- Ontologies for document categorization

Semantic integration

- Exploitation of heterogeneous information sources
  - Different representational techniques (e.g. spatial, object-oriented)
  - Textual sources: doctrine, procedures, lessons learned
- Concept of a Knowledge Server:
  - Use of an ontology middleware layer
  - Facilitate semantic integration of heterogeneous sources

A Priori MSDF / STA / RM Database Architecture



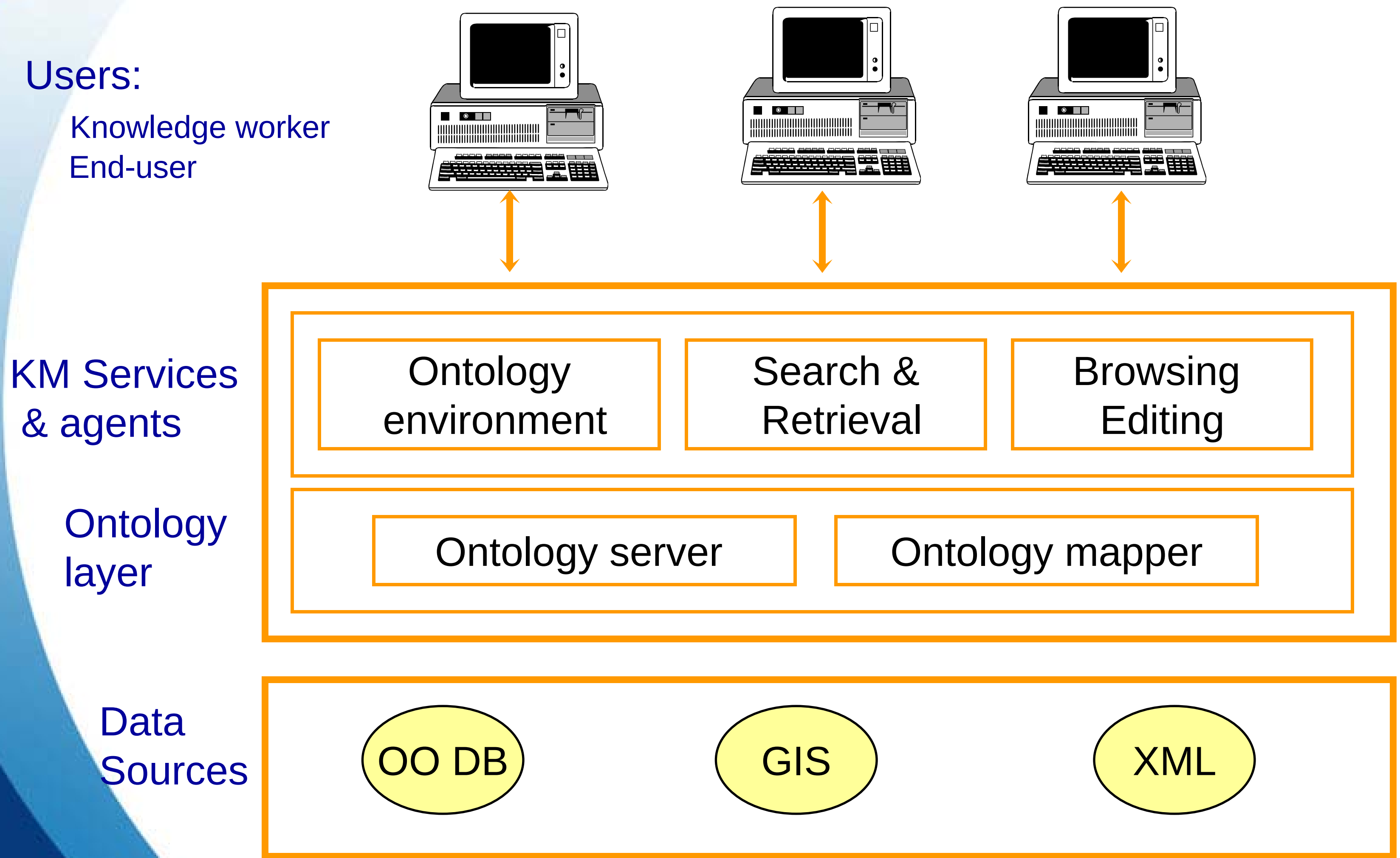

MSDF/STARM LIBRARIES STUDY
OO-DB
XML Query
GIS Information
Country Informations
Select Country (276 entries in the database)
Netherlands (NL)
Name : Netherlands
Code : NL
Allegiance : Friend
Spoken Languages : DUTCH,
Infrastructures :
Rat31-SL (RAT31SLINF) - Fixed Sensor
Name : Rat31-SL
Short Name : RAT31SLINF
Type : FIXED_SENSOR
Importance : UNKNOWN
Sensor : Rat-31SL
Platform Information
Select Platform (2232 entries in the database)
F-16A FIGHTING FALCON (F16A)
Specs
Subclass Info
Name : F-16A FIGHTING FAL
Short name : F16A
Type : AIR FIXED WING MILI
Subtype : FIGHTER OR INTE
Role : " lightweight fighter ai
Lethality : VERY LARGE
Maximum Velocity : 591.610
Minimum Velocity : 128.611
Cruise Velocity : 272.65533
Weapon :
AGM-84D Harpoon (AGM84D)
Sensor :
AN/APQ-159(V) (APQ159)
Countries :
Netherlands (NL)
Weapon Information
Select Weapon (624 entries in the database)
AGM-84D Harpoon (AGM84D)
Specs
Subtype Info
Name : AGM-84D Harpoon
Short name : AGM84D
Minimum range : Unknown
Maximum range : 150000.0
Sensor Information
AN/APQ-159(V) (APQ159)
Name : AN/APQ-159(V)
Short name : APQ159
Maximum range : 74080.0
Usage : family of forward- lo
Search time : Unknown
Band : "I, J"

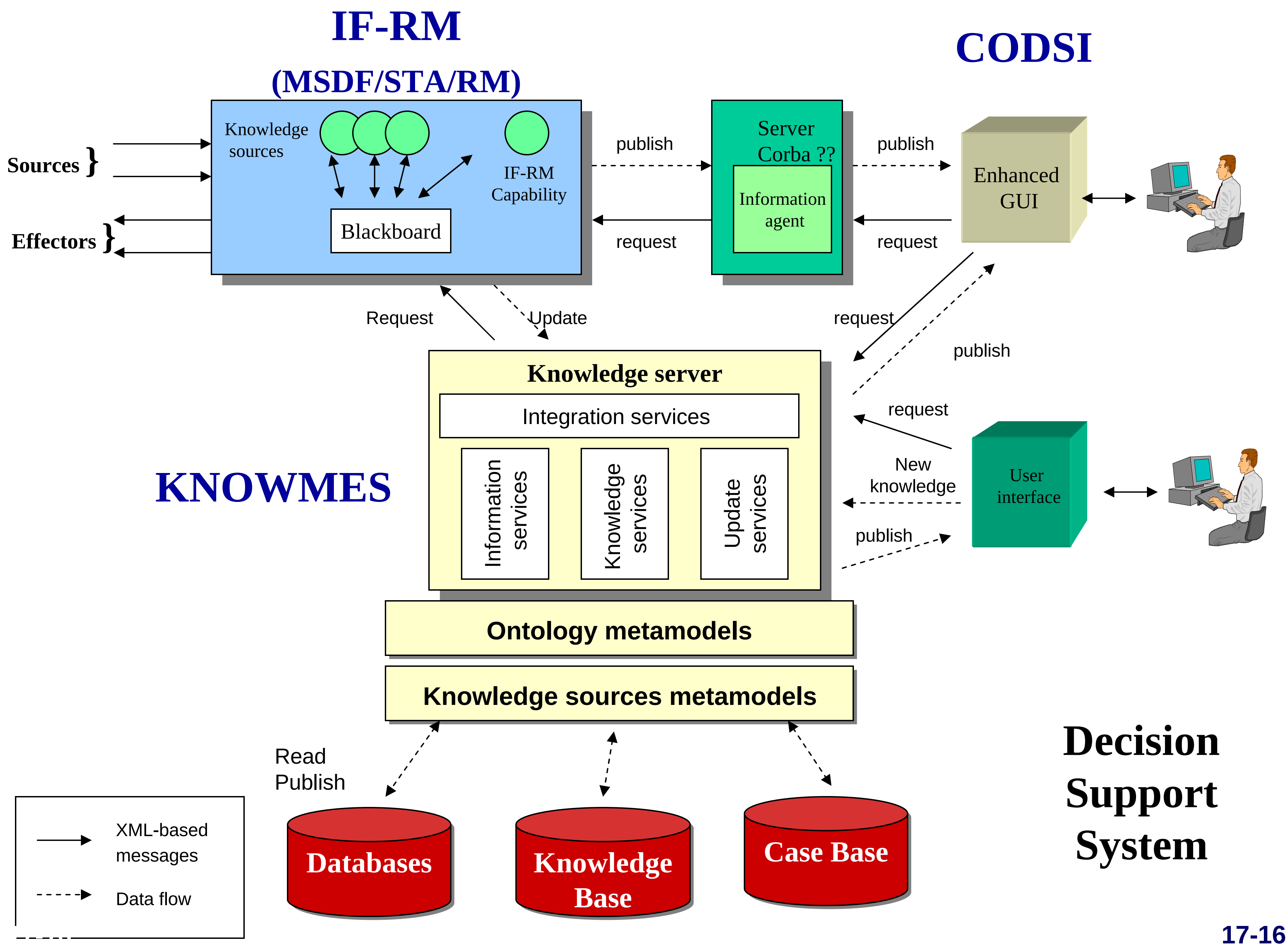
A priori database content

Paper No.12
(Valin et Bossé)

MSDF	Entity Information	Category, lethality, phys. Dimension, …
	Geo-political information	Allegiance, language, platform list, …
	Electro-magnetic Radiation	Bandwidth, frequency, range, …
	Sensor information	Location, uncertainties, …
STA	Extension of entity	Entity role, crew, weapon capacity …
	Extension of geo-political	Location of infrastructures, …
	Relations between objects	Formation, communication schemes, …
	Behaviours of objects	Predefined patterns, …
	Geo-political information	Terrain elevation, water plans, roads, special areas, …
RM	Force resources	Own force weapon and sensor capabilities, …
	Doctrine & Procedures	Engagement procedures, doctrine vs mission, …

KNOWMES: a Knowledge server to support C2 applications





IF-RM
(MSDF/STA/RM)
CODSI
Sources
Effectors
Knowledge sources
IF-RM Capability
Blackboard
publish
request
Server Corba ??
Information agent
publish
request
Enhanced GUI
Request
Update
request
publish
Knowledge server
Integration services
Information services
Knowledge services
Update services
request
New knowledge
publish
User interface
KNOWMES
Ontology metamodels
Knowledge sources metamodels
Read
Publish
Databases
Knowledge Base
Case Base
XML-based messages
Data flow
Decision Support System

Ontology-based search & retrieval

- Query formulation
  - Use of ontologies as a common terminology
  - Unified query to perform federated search

- Query processing
  - Ontology mapping to sources → reformulate queries in the query languages of the different sources
  - Exploit relationships between concepts to provide more relevant results:
    - Abstraction relationships
    - Equivalent classes (or synonyms), Acronyms

Ontologies for document categorization

Aim:

- Organize unstructured information according to a taxonomy
- Facilitate efficient information storage and retrieval

→ Ontology structure exploited for document indexing and categorization

- Combine statistical and semantic indexing processing
- Natural Language processing techniques supported by an ontology to provide semantic indexes
- Exploit the taxonomy as a structure to categorize documents

Applications of the concepts

- KnowMES: Knowledge server in support of Command and Control applications
- COP21 TD Knowledge Portal
- Lessons Learned Management System
  - Organize military lessons learned along a taxonomy dimension
  - Provide ontology-based search engine within lessons learned for LL analysts and military planners

Paper No.22
(Champoux et al.)

- ADAC: Automatic Document Analyzer and Classifier
  - Document indexing, classification, clustering, diagnostic
  - Prototype developed in the terrorism domain

Conclusion and perspectives

- Ontological engineering
  - Methods, formalisms, tools
  - Ontology mapping between different knowledge structures
  - Management of extensible ontologies, ontology learning

- Knowledge management environments
  - Concept of knowledge servers and portals
  - Integration of heterogeneous information and knowledge sources
  - Provide KM services both to applications and to users
    - Semantic search and retrieval,
    - Contextual reasoning, filtering
    - Knowledge discovery from large data sets

Questions ?

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